"The small pecuniary resources of our Meteorological Institute, which now includes ninety-seven stations, do not permit me to publish the daily means. I have therefore had to content myself with five-day means; but I think that by the consequent calculation of deviations I have brought some questions nearer to a solution. But I have to do this work by myself, and, overcharged as I am besides with official duties, I do not think I shall long be able to continue to master it. The resources which the British Association offers to all scientific undertakings in England will make it possible for you to establish in a thorough manner the constants of a climatology of England, and to investigate on this climatological basis the meteorology of England.

"I had long proposed to myself to write from my own point of view a pamphlet 'how to observe' in meteorology; but when one has, as I have constantly, to give lectures in the day, and hold examinations in the evening till nine o'clock, much that has been contemplated is left undone..... In regard to telegraphic communications, Admiral FitzRoy once said to me that reports from Eastern Europe were of little interest for England. This may be granted where it is question of the storms which assail the English and Irish coasts themselves. But the commerce of the Baltic is for the greater part in the hands of Englishmen, and I think that it would therefore be conducive to English interests also if the efforts were facilitated which are made by others to lessen the dangers to shipping in the Baltic. As it is precisely north-west storms which are the most dangerous in that sea, communications from England are wanted for this. Among the numerous telegraphic communications received here daily, there are none from England. Would it not be possible to arrange an exchange, if only for one or two stations? The communication might be made through Tönningen, by the cable, so as to avoid the German-Austrian Telegraph Company, which declines to afford a gratuitous passage for our messages.

"Harbour signal arrangements are now established at Memel, Pillau, Neufahrwasser, Stolpemünde, Rügenwalde, Colbergermünde, Swinemünde, Greifswald, Stralsund, and Barth."

June 15, 1865.

Major-General SABINE, President, in the Chair.

The Rev. W. R. Dawes, Mr. George Gore, Dr. George Harley, Mr. W. Huggins, Mr. Fleeming Jenkin, and Mr. W. K. Parker, were admitted into the Society.

The following communications were read:—

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I. "Description of a Rigid Spectroscope, constructed to ascertain whether the Position of the known and well-defined Lines of a Spectrum is constant while the Coefficient of Terrestrial Gravity under which the Observations are taken is made to vary." By J. P. GASSIOT, V.P.R.S. Received May 18, 1865.

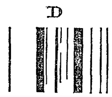
Shortly after my large spectroscope * had been removed to Kew Observatory, Mr. Stewart mentioned to me that he had had some conversation with Professor Tait of Edinburgh, as to the practicability of having a spectroscope constructed so as to preclude all errors of observations arising from a displacement of the prisms or the shifting of any of the fixed portions of the apparatus.

The particular object Mr. Tait and Mr. Stewart had in view, was the determining whether the positions of the known and well-defined lines of the spectrum are constant while the coefficient of terrestrial gravity, under which the observations are taken, is made to vary, Mr. Stewart considering that, provided an instrument could be constructed so rigid in all its parts as to preclude all possibility of error, the observations might be made in balloon ascents, varying from two to four miles.

I consulted with Mr. Browning as to the practicability of constructing the spectroscope. He considered such an instrument could be made, with sufficient rigidity in all its parts, to examine with great accuracy any given portion of the spectrum which might be selected, and for which the prisms would have to be adjusted and fixed. I communicated with Mr. Coxwell relative to the balloon ascents which would be required, and then determined on having the spectroscope constructed.

On testing the alteration in the position of the lines arising from change of temperature, it was soon ascertained that the difficulty of constructing a truly rigid spectroscope was far greater than had been anticipated.

By the description of the apparatus, it will be seen that the prisms are arranged so as to bring the D-lines into the centre of the field of view (fig. in margin), with a few of the fainter lines on each side; a perpendicular *fixed* line, and two cross *moveable* lines in the cobweb micrometer eyepiece, affording the means of measuring to $\frac{1}{10,000}$ of an inch, whatever alteration takes place in the position of the lines.



D-lines as seen with the Rigid Spectroscope.

The observations having been originally intended to be made in balloon ascents, the construction of the spectroscope had necessarily to be considered in reference to some portable and easily manageable form, and it was particularly desirable that its weight should be as low as possible. These conditions were obtained by constructing and mounting it in a T-shaped frame of gun-metal: in this manner the instrument was completed so as to weigh little more than 40 lbs.; but on carefully examining the readings day by day in Mr. Browning's workshop, the errors arising from changes in the temperature were ascertained to be so variable that no reliable result could have been obtained.

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* Proceedings of Royal Society, vol. xii. p. 536.

These preliminary observations were nevertheless so far valuable, for they proved that changes of temperature were taken up very slowly by the prisms, and that it would be consequently useless to employ the instrument in balloon ascents where rapid fluctuations of temperature would continually occur.

I then determined to attempt the construction of a rigid spectroscope with which observations might be made either on board a vessel or on land, in various latitudes; and as the question of the total weight of the apparatus became no longer of paramount importance, Mr. Browning decided on mounting the instrument in cast iron. The adjustments of the telescope being dispensed with, it was mounted in two cast-iron blocks, and fixed on a bed of slate; the prisms, with their adjustments, were attached to an iron plate, the plate being bolted to the same slate-bed. In this arrangement the observations still showed discrepancies, which were considered to arise from changes in the adjustments of the prisms, produced by alterations of temperature. Mr. Browning then removed all the adjustments of the prisms, and also the iron bed-plate, bolting the prisms on the bed of slate, and securing their correct position by filing and scraping. Full particulars of this arrangement will be found in the description of the apparatus.

The instrument has been carefully examined by Mr. Stewart, not only at Kew Observatory but also from time to time during the progress of its construction, as well as after it was completed in Mr. Browning's workshops; and it may now be considered that, with ordinary care during its transit from place to place, any observations made with it can be depended on as far as the mechanical arrangement is concerned.

I am indebted to Mr. Browning for the description of the apparatus, with the notes of the readings as they were made by himself.

The optical arrangement is as follows:—In order to obtain great refractive power in a moderate compass, the prisms were arranged as in Plate VI. fig. 1. P and P′ represent two prisms of heavy flint glass, having sides 2½ inches high, and 3 inches long. These prisms have refracting angles of 45°. They are arranged at the minimum angle of deviation for Fraunhofer's line D. R represents a prism of similar material and dimensions, but with a refracting angle of 22° 30′, that is half P and P′.

The dense flint glass of which these prisms are composed was made by Messrs. Chance Brothers and Co. It has a specific gravity of 3·9. Its mean refractive index is 1·665, and its dispersive power 0·0752. The prism R has the side further from P and P′ silvered. The nearest side is placed at the same minimum angle of deviation from P as P is from P′.

D and D′ represent a compound prism, formed by cementing a very small diagonal prism D′ on to a large diagonal prism D with a transparent cement, in such a manner that two of the plane surfaces are parallel. They are both made of hard white optic crown glass, cut from the same block. O is an achromatic object-glass of 2·3 inches aperture, and 3 feet focal length. M is a cobweb micrometer eyepiece, having one fixed vertical web, and two which are crossed, moving together; also a fine rack in the field of view, which serves to register whole turns of the micrometer head (fig. 4). S is a pair of knife-edges. The action is as follows: when any source of light is brought in front of the knife-edges S, some of the rays emitted pass through them, and unchanged through the double diagonal prism D, D′, as shown on a large scale in diagram 2. As the object-glass O is placed at its focal distance from the knife-edges, the rays in passing through it are rendered parallel; on entering and emerging from P′, P these rays suffer refraction, and also, if the light be not homogeneous, dispersion. The same effects are produced as the rays enter the first surface of R, and again emerge from it, after being reflected from the further side, which, as has been previously mentioned, is silvered. They now retrace their way through the prisms P and P′, the refraction and dispersion being doubled in this return passage. In this manner a result is obtained equal to that which would be produced by five prisms, if employed in the ordinary manner.

Repassing through O, this compound lens, which before acted as a collimator, now acts as the object-glass of the telescope T. The cone of rays produced by this lens falls on the prism D D′, figs. 1 & 2, and is reflected from the diagonal side, a loss of light determined by the size of the small prism D being experienced; but as this prism need be but little more than the length and width of the slit formed by the knife-edges, the loss may, practically, be considered unimportant.

In figs. 1 & 2 the continuous line represents the rays of light in their first passage through the prisms, and the dotted lines the same rays returning through the instrument. The image of the slit is viewed, and any change in its position observed, by means of the micrometer eyepiece M. Owing to the power of the instrument, only a very small portion of the spectrum can be seen at once in the field of view. The reflecting prism R is, however, provided with a tangent screw motion, which affords the means of bringing any portion of the spectrum into the field of view that it may be desired to examine.

Although having to contend with several disadvantages on the score of reflexions not made use of in spectroscopes of the ordinary construction, and which of course cause loss of light and tend to deteriorate the definition, yet it will, I think, be admitted that the performance of the instrument is satisfactory.

Mr. W. Huggins has seen two bright lines between the D-lines produced by the flame of a common spirit lamp; and several persons have seen on different occasions from five to seven lines between the D-lines in the solar spectrum. This is equal to the performance of my large spectroscope, with which the solar spectrum is now being mapped at Kew Ob-

Fig 1.

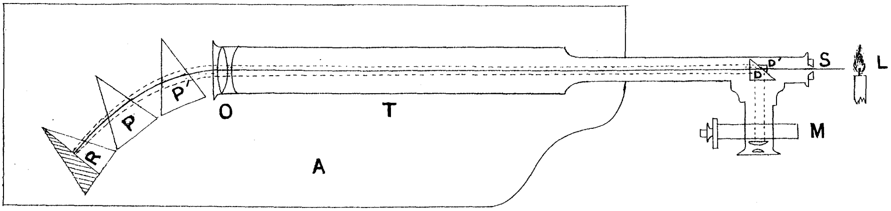


Fig 2.

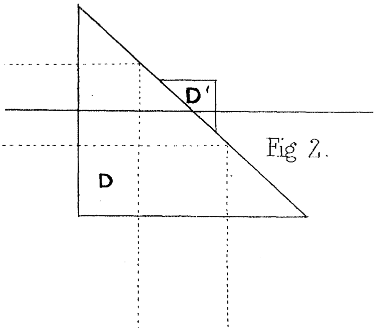


Fig 4.

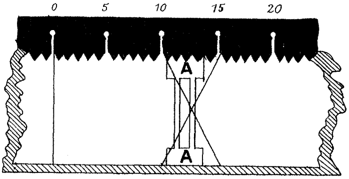
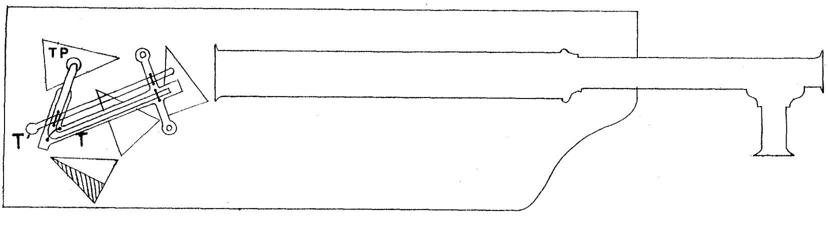


Fig 3



J. Basire, lith.

servatory, although that instrument has nine prisms. The prisms of that spectroscope are, however, but little more than half the size of those in the rigid instrument now described. It is to the large size of the prisms, and the greater aperture and focal length of the object-glass, that the superior performance of this instrument must be attributed.

The temperature of the air and of the prisms is thus observed:—A third prism (T P, fig. 3), exactly similar to P and P′, is mounted on the slate block. This prism has a hole about $\frac{1}{2}$ an inch diameter and $1\frac{1}{2}$ inch deep drilled in it vertically. A thermometer (Plate VI. T, fig. 3) with a fine cylindrical bulb is inserted in this hole, the intervening space being packed tight with copper filings. The upper part is covered with a layer of fused shell-lac. That the half prism may be about the same temperature as the whole prisms, another half is cemented to it. To avoid confusion, this half is not represented in the diagrams. The thermometer, after leaving the prism, is bent at right angles, and is carried across the top of the prisms on a light metal frame. Another thermometer (T′, fig. 3), whose bulb is in the air, its object being to denote the temperature of the air around the prisms, runs parallel with that just described. Both the prisms and thermometers are enclosed under a metal cover, for the purpose of equalizing the temperature and protecting them from injury. This cover has a long slip of stout plate-glass let into the upper part of it, through which the thermometers can be seen, and their readings observed. The micrometer eyepiece and the cell containing the object-glass are each mounted on distinct iron blocks. The body of the telescope which fills up the intervening space is mounted on two separate iron blocks not connected with those just mentioned. The tube which forms the body overlaps at one end the tube of the eyepiece, and at the other the mounting of the object-glass, but without being in contact with either. By this means the change of length in the body-tube, produced by change of temperature, by far the most considerable change we have to contend with, is prevented from exerting any influence on the indications given by the instrument.

The homogeneous light of the sodium-flame is employed, and the micrometer wires are lighted up by the contrivance shown in fig. 4. A portion of the cap on which the knife-edges are fitted is cut away, and the light which is thus admitted enables the wires, and the rack that serves to register whole turns of the micrometer screw, to be seen distinctly *. A whole turn of the micrometer screw values $\frac{1}{100}$ of an inch, so that the first reading in Table I. might have been written 0·0552. In making remarks on differences in the readings, they will be expressed in this manner, the reading of the line D decreasing with the rise in the temperature of the prisms.

The object in taking the readings of the D-line, which are appended, was

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* In fig. 4 the bright lines of sodium, as seen in the rigid spectroscope, are represented; the spaces A, A are cut away, allowing the light from the sodium-flame to enter and illuminate the field enough to render the cobwebs visible.

to endeavour to determine the temperature corrections which it will be necessary to apply to the results obtained by the instrument, and also to find if the line resumed its position exactly after the instrument had been subjected to considerable changes of temperature, or carried from place to place. From Tables III. and IV. it may be noted that the readings have a constant downward tendency. To endeavour to account for this retrogression, I can only venture to hazard the suggestion that the index of refraction of the glass of which the prisms are made may be slightly varying from some change due to annealing not having yet been entirely completed.

Although showing generally a downward tendency, the decline is not quite uniform, and there are some apparent discrepancies in the readings; these may be errors of observation, arising principally from differences of intensity in the source of illumination. Such differences tend to alter the width of the bright line observed; and as one of its edges is taken for the point of measurement, the position of the line is apparently changed. Mr. Stewart is, however, of opinion that these variations are so slight that they will not be likely to interfere with the instrument being used for the purpose for which it was designed.

TABLE I.

Readings of one of the D-lines taken with the Rigid Spectroscope at the Minories.

Date.	Temp. Air.	Temp. Prism.	Micrometer.	Difference in divisions.
	°	°		
February 1.	57·5	52·5	5·52	1·20
„ 1.	88·0	82·5	6·72	
„ 2.	90·0	82·5	6·55	1·27
„ 3.	52·0	52·5	5·28	
„ 6.	56·0	52·5	4·98	1·17
„ 6.	90·5	82·5	6·15	
„ 7.	53·0	53·0	5·05	1·18
„ 7.	95·5	82·5	6·23	
„ 9.	54·0	52·5	4·85	1·25
„ 9.	84·0	82·5	6·10	
„ 11.	57·5	52·5	4·85	

Results from 6th to 11th:—

Variation in temperature correction for a change of temperature of 30° .... 0·0007 inch.

Separation of D-lines .... 0·004 inch.

TABLE II.

Date.		Temp. Air.	Temp. Prism.	Readings.	Difference for 20°.
		°	°		
February 16.	....	48·5	42·5	4·60	= 0·96
„ „	....	58·0	52·5	5·09	
„ „	....	69·5	62·5	5·56	
„ 17.	....	50·0	42·5	4·	= 0·92
„ „	....	57·5	52·5	5·08	
„ „	....	67·5	62·5	5·54	
„ 18.	....	48·0	42·5	4·60	

Variation of temperature correction for a change of temperature of 20° .... 0·0004 inch.

TABLE III.

Date.		Temp. Air.	Temp. Prism.	Readings.
		°	°	
February 20.	....	56·0	52·5	4·98
„ 21.	....	56·0	„ „	4·88
„ 22.	....	58·0	„ „	4·90
„ 23.	....	53·0	„ „	4·89
„ 24.	....	53·5	„ „	4·92
„ 27.	....	53·0	„ „	4·88
„ 28.	....	52·5	„ „	4·94
March 1.	....	56·0	„ „	4·96
„ 2.	....	56·5	„ „	4·93
„ 7.	....	56.0	„ „	4·84
„ 8.	....	56·0	„ „	4·84
„ 9.	....	58·0	„ „	4·82

Decrease of zero, 0·0016 of an inch.

Having thus far satisfied ourselves by observing under varied temperatures, and also that the removal of the instrument to different parts of Mr. Browning's premises did not affect the readings on the 22nd of March, the apparatus was removed in a cart to Kew Observatory, and placed in one of the rooms for observing, when the following readings were made :—

Date.		Temp. Air.	Temp. Prisms.	Reading.
		°	°	
March 23.	....	45·0	42·2	4·57

Mean of readings taken in the Minories, at a temperature of 42°·5, 4·60 ; change of zero during the transit, 0·0003 of an inch.

Observations were subsequently continued under the direction of Mr. Stewart.

TABLE IV.

Readings taken by Mr. Beckley at Kew Observatory.

Date.		Temp. Air.	Temp. Prism.	Micrometer reading.
April 3.	....	57°·5	56°·8	5·73
„ 28.	....	57·2	56·8	5·53
„ 3.	....	55·1	54·3	5·66
„ 6.	....	56·0	54·5	5·41
„ 9.	....	55·0	58·4	5·44
May 3.	....	53·6	58·4	5·47

Decrease of zero in the month, ·0026.

On the 5th of May the spectroscope was removed to the rooms of the Royal Society, Burlington House, where it still remains.

The result of observing under a varied temperature of 40° Fahr., the carrying of the instrument from the Minories to Kew Observatory, and subsequently to the Royal Society, without affecting the readings, may be taken as evidence that with ordinary care the spectroscope can now be used with reliance as to the rigidity of its construction, thus fulfilling the conditions which are indispensable for obtaining correct observations.

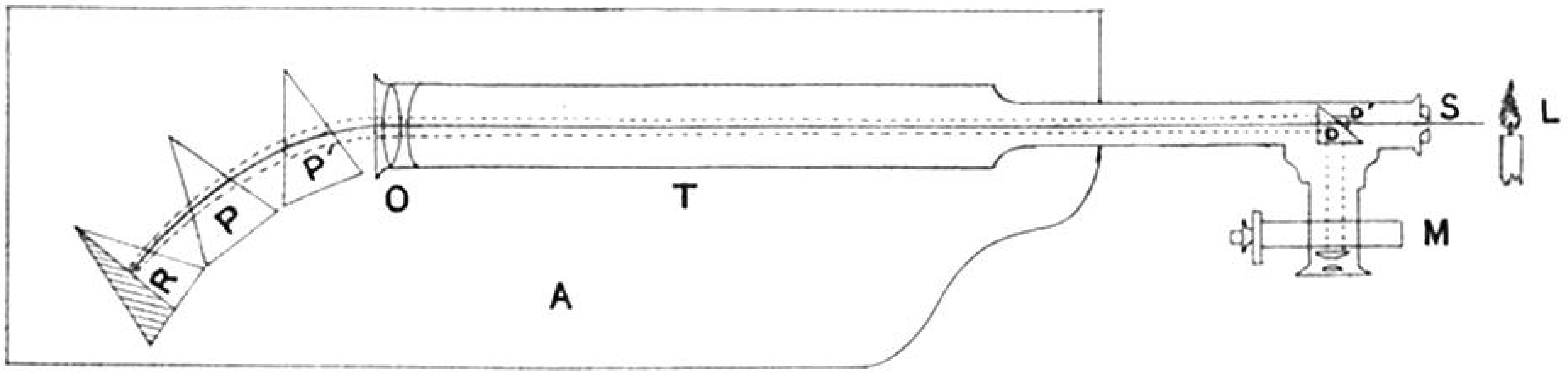
It will be observed that it was my intention to have made arrangements with Mr. Coxwell for the observations being made with his balloon, but the weight of the entire apparatus (approaching two hundred weight), and still more the difficulty of obtaining a uniform temperature throughout the prisms, renders observing in this manner very difficult, if not impracticable; I therefore suggested to Mr. Stewart that, if the observations were made in different latitudes, the object sought would be obtained in a more satisfactory manner.

The best, and probably the most satisfactory mode of observing, would be to obtain the sanction of the Admiralty to allow the spectroscope to be placed on board one of Her Majesty's vessels about visiting various latitudes; continued observations could then be made, and the result thereof from time to time forwarded to Kew Observatory.

Mr. Stewart writes me, that to this time it has been assumed, without proof, that the change of the coefficient of terrestrial gravity does not in itself alter any other coefficient of a body; and if a reason is asked, none can be given, since gravity is a force of the nature of which men of science are confessedly ignorant, and that it would therefore be very desirable that experiments should be undertaken with the view of setting this matter at rest.

It is to determine this, as far as the index of refraction is concerned, that the spectroscope I have described has been constructed, and the assistance of the President and Council of the Royal Society will be asked, in order that the observations may be made with this apparatus by some trustworthy observer, on board any of Her Majesty's ships, from one point to another of the earth's surface.

Fig 1.



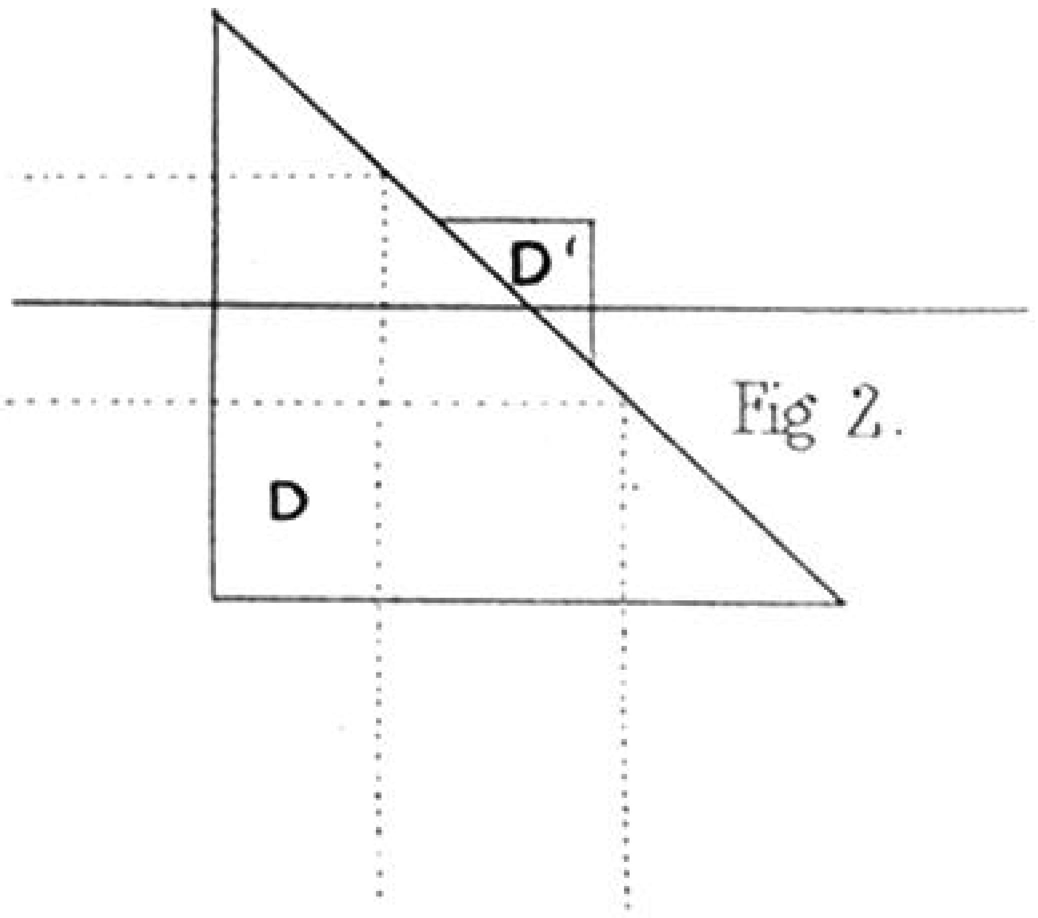


Fig 2.

Fig 4.

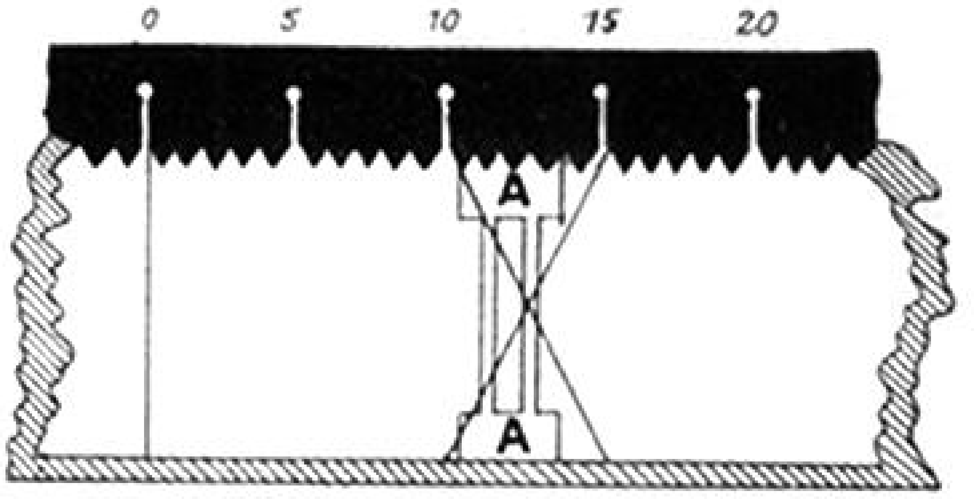
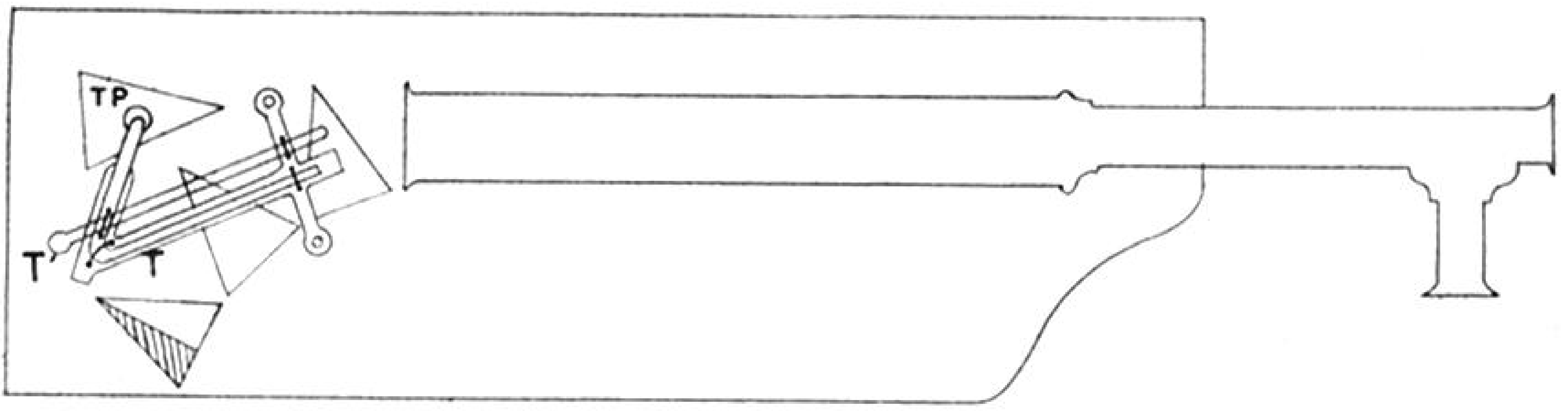


Fig 3.



J. Basire, lith.